

Collisions of gluon strings

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in collaboration with S. J. Brodsky, A. S. Goldhaber and R. W. Brown

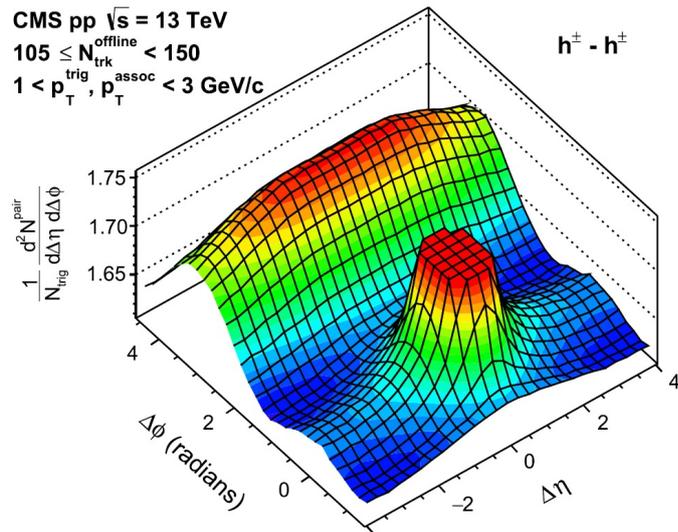
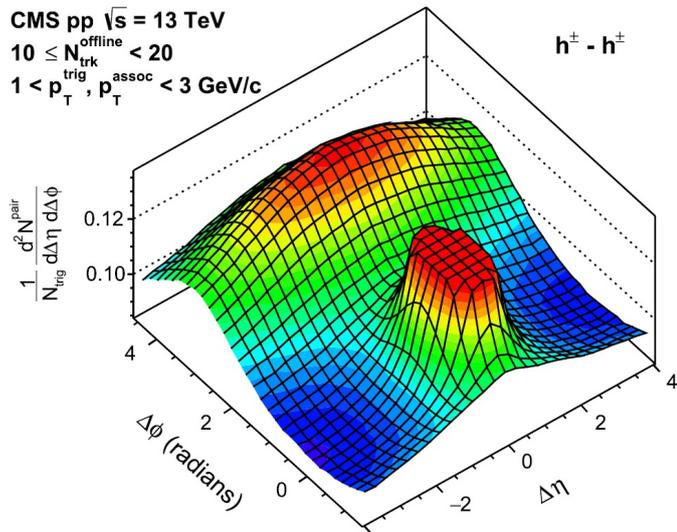
The ridge effect observed in high multiplicity events in proton-proton scattering at LHC can be due to the collisions of flux tubes in the projectiles which are in turn related to the fundamental physics of color confinement. We discuss observable effects due to gluon string collisions in electron-proton and peripheral proton-proton scattering related to scattering of photons. The final-state multiplicity and elliptic flow are foreseen to exhibit variation due to collisions of gluon strings at the level of several percent.

S. J. Brodsky, S. D. Głazek, A. S. Goldhaber, R. W. Brown, SLAC-PUB-17106, arXiv:1708.07173 [hep-ph]

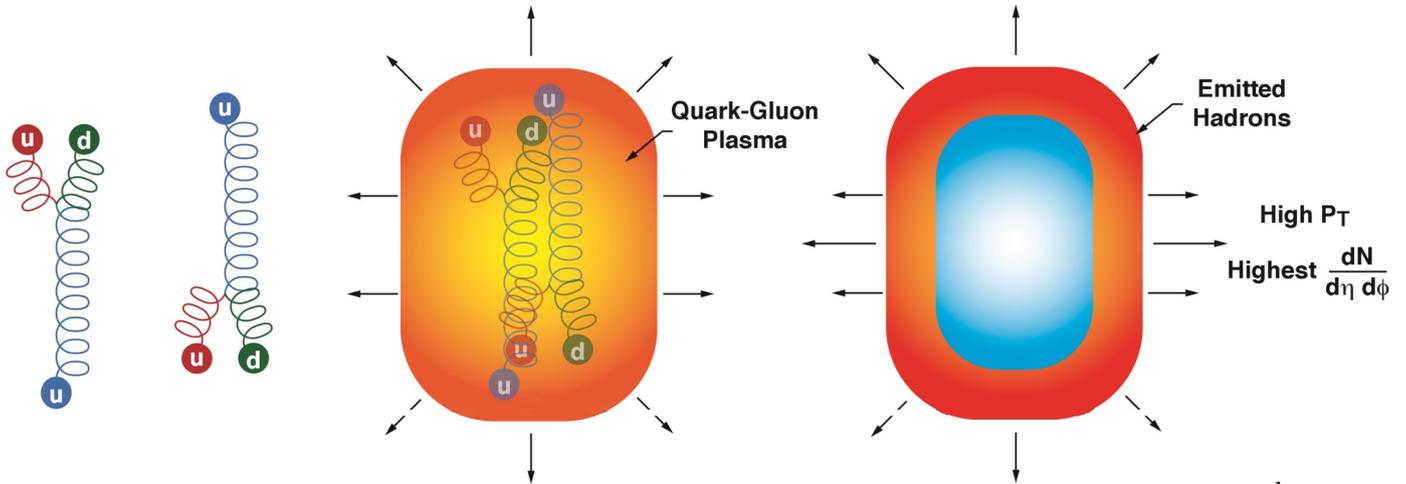
S. D. Głazek, S. J. Brodsky, A. S. Goldhaber, R. W. Brown, in preparation

Ridge effect in pp

The CMS Collaboration / Physics Letters B 765 (2017) 193–220

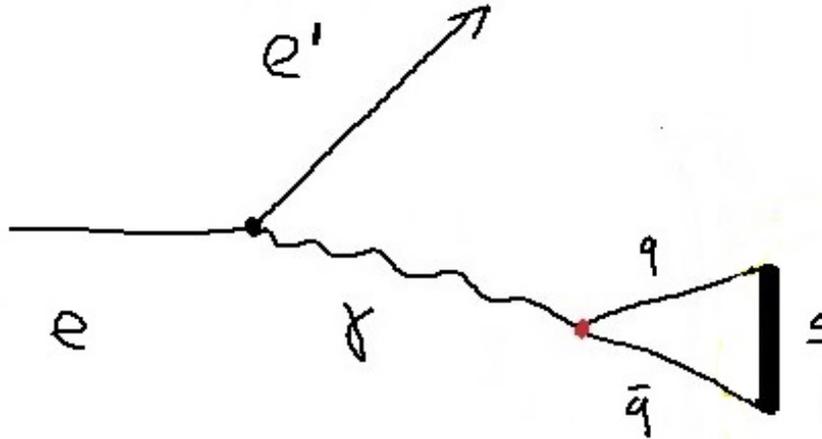


Collision of quark-diquark strings.

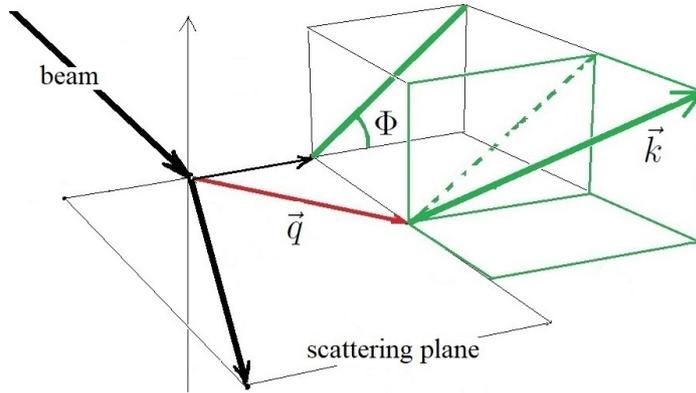


J. D. Bjorken, S. J. Brodsky, A. S. Goldhaber, PLB 726, 344 (2014).

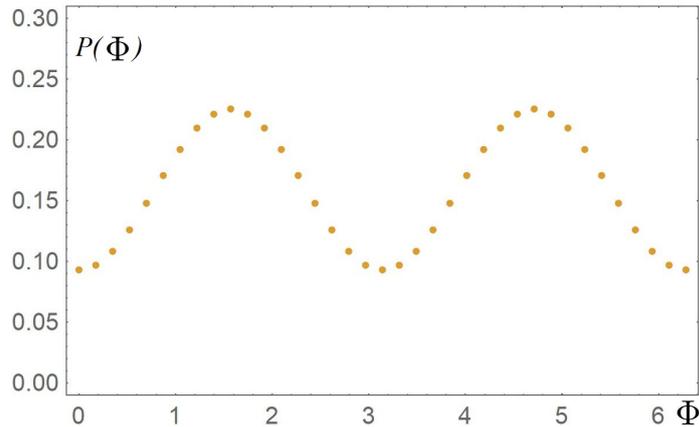
Virtual gluonic strings (any charged projectiles)



Scattering develops quark-anti-quark pair connected by a gluon string.

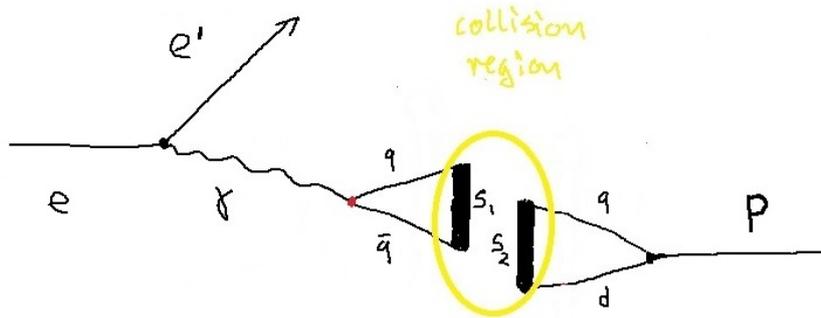


Gluon string lies along $q\bar{q}$ relative momentum and forms the azimuthal angle Φ with the scattering plane.

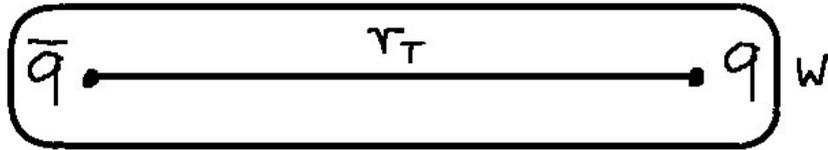


Example of probability $P(\Phi)$ of gluon string orientation The incoming electron momentum is 7 TeV. Electron scatters with momentum transfer of square $q^2 = -1.4 \text{ GeV}^2$, gaining 1 GeV of momentum transverse to the beam and losing 1/4 of its initial momentum along the beam. The same result holds for a proton.

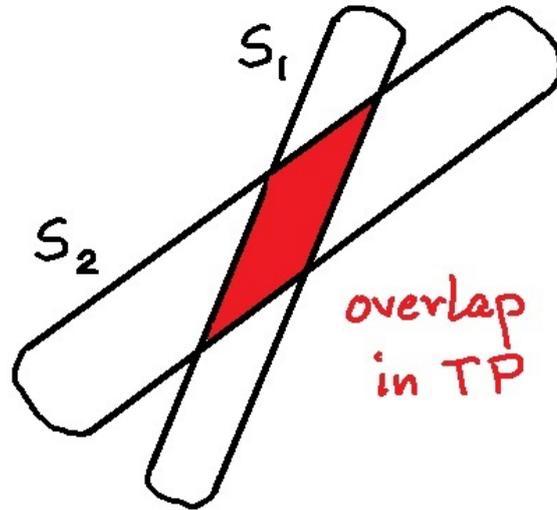
Collective correlation in DIS



Electron scattering on protons proceeds through a collision of gluon strings.



Qualitative view of the two-dimensional string shape on the transverse plane



The number of partonic collisions in a collision of two strings S_1 and S_2 , is assumed to be proportional to the overlap area in the TP, in which the strings are seen as shown when they are looked at along the beam.

**DIS final-state multiplicity expected maximal
when elliptic flow is aligned with the lepton plane**

gluon size w

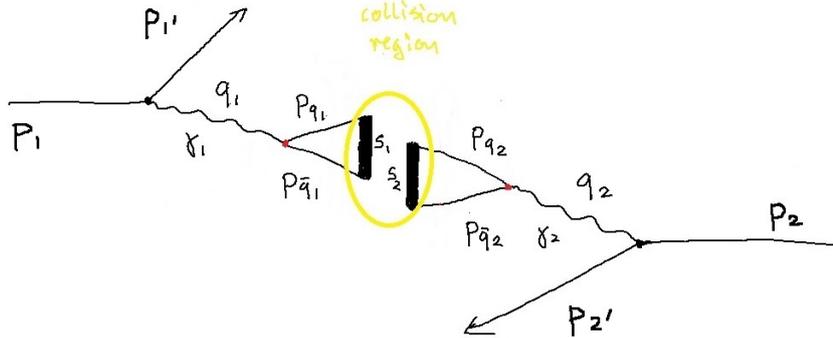
use the RGPEP

talk by Kamil Serafin, Thursday, 11 AM

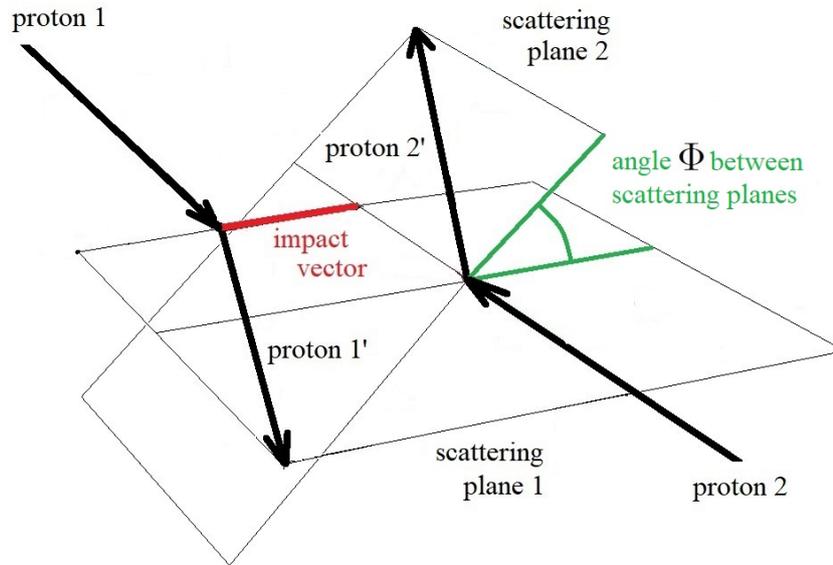
gluon string = chain of gluons

$$n_{\text{coll}}(\vec{x}_T, \vec{b}, \vec{r}_1, \vec{r}_2) = \sigma \rho_1(\vec{x}_T - \vec{b}/2, \vec{r}_1) \rho_2(\vec{x}_T + \vec{b}/2, \vec{r}_2).$$

Collision of gluon strings at LHC



The peripheral $p_1 p_2 \rightarrow p_1' p_2' X$ scattering proceeds through collision of gluon strings S_1 and S_2 .



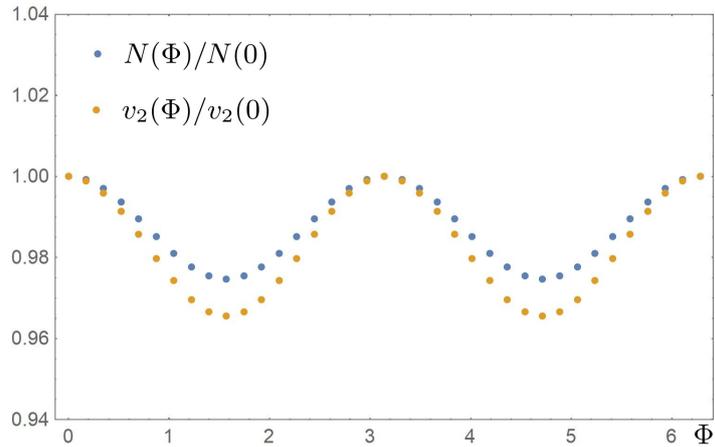
Angle Φ between scattering planes

Multiplicity of X

$$N(p'_1, p'_2) = \frac{C_N}{\sigma_p} \int d^2b \int d^3r_1 P(\vec{r}_1, p'_1, p_1) \int d^3r_2 P(\vec{r}_2, p'_2, p_2) \\ \times \left[1 - e^{-N_{\text{coll}}(\vec{b}, \vec{r}_1, \vec{r}_2)} \right] N_{\text{coll}}(\vec{b}, \vec{r}_1, \vec{r}_2)$$

Elliptic flow in X

$$v_2(p'_1, p'_2) = \frac{C_v}{\sigma_p} \int d^2b \int d^3r_1 P(\vec{r}_1, p'_1, p_1) \int d^3r_2 P(\vec{r}_2, p'_2, p_2) \\ \times \left[1 - e^{-N_{\text{coll}}(\vec{b}, \vec{r}_1, \vec{r}_2)} \right] \varepsilon_2(\vec{b}, \vec{r}_1, \vec{r}_2)$$



Example of minimal-bias average ratios of multiplicity, $N(\Phi)/N(0)$, and elliptic flow, $v_2(\Phi)/v_2(0)$

Beyond minimal bias

$$N > f N_{\max}$$

For $f = 1/2$ and $f = 0.75$,

the multiplicity ratio $N(\pi/2)/N(0)$ decreases

from about 0.975 to about 0.93 and 0.92, respectively.

The elliptic flow ratio $v_2(\Phi)/v_2(0)$ drops

from about 0.965 to about 0.90 and 0.875.

$b > 4$ **fm**

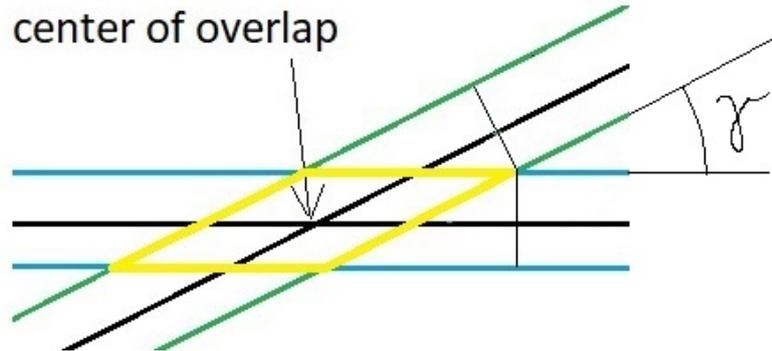
multiplicity drops 40 times

azimuthal variation increases about twice

also: variation of string width and length limit – the azimuthal effect persists

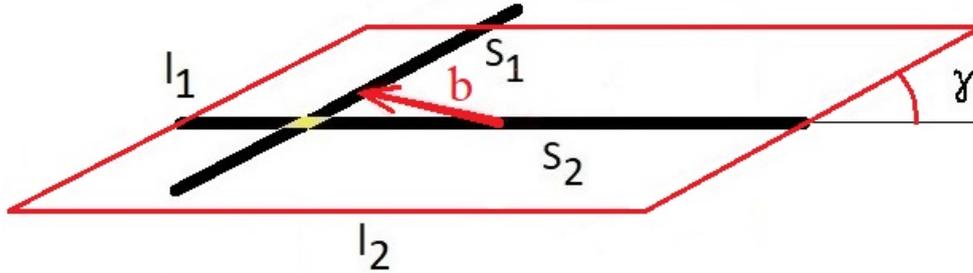
Conclusion:

**We may see collisions of strings of gluons
in lepton and hadron scattering.**



Rhombus overlap area for thin strings; its area and eccentricity are independent of string lengths:

$$a_{\text{rhombus}} = w^2 / |\sin \gamma|, \quad \varepsilon_{2\text{rhombus}} = |\cos \gamma|$$



Parallelogram in the transverse plane, over which the end of impact vector \vec{b} ranges for some fixed values of the strings lengths l_1 and l_2 and their relative azimuthal angle γ in the transverse plane. In almost entire parallelogram, the overlap area and its eccentricity are the same when the ratios w/l_1 and w/l_2 are negligible. The overlap area is marked in yellow.